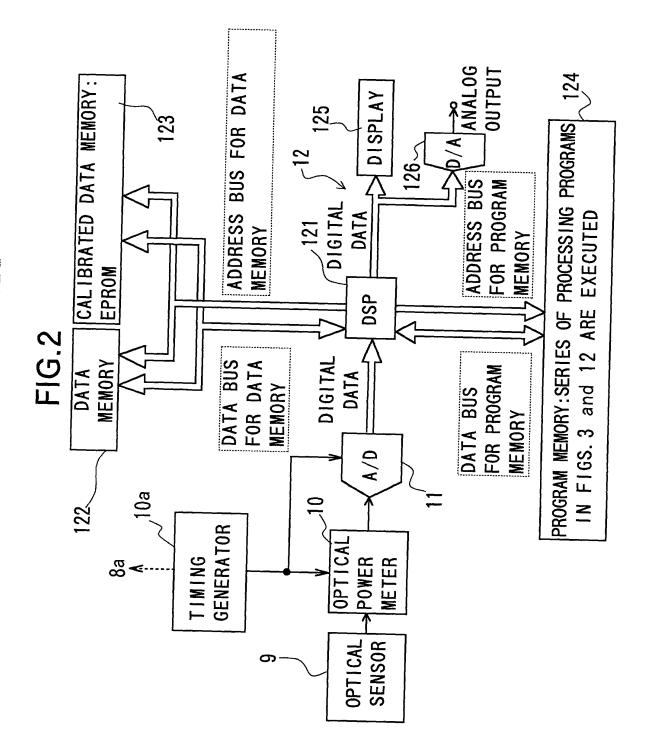
Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 1 of 61

SIGNAL PROCESSING PART 6a FABRY-PEROT LOAD CELL 2×2 COUPLER VARIABLE GAP TYPE FABRY-PEROT INTERFEROMETER OPTICAL POWER METER

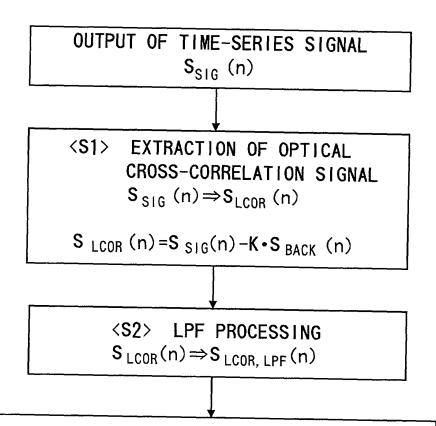
FIG.1

Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 2 of 61



Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 3 of 61

FIG.3

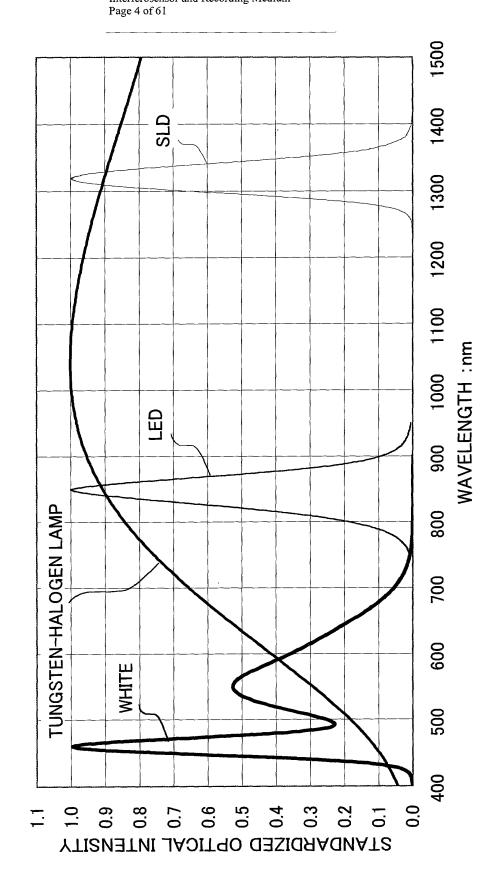


<S3> DETECTION OF EITHER MINIMUM
POSITION OR MAXIMUM POSITION

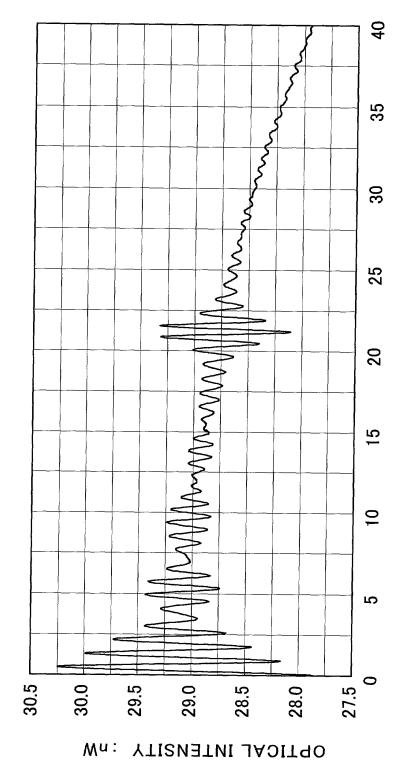
SMOOTHING DIFFERENTIAL $S_{LCOR, LPF}(n) \Rightarrow dS_{LCOR, LPF}(n)/dn$

CALCULATION OF ZERO-POINT POSITION $dS_{LCOR, LPF}(X)/dX=0 \Rightarrow X_{PEAK}$

F I G. 4



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"



MOVING DISTANCE: μ m

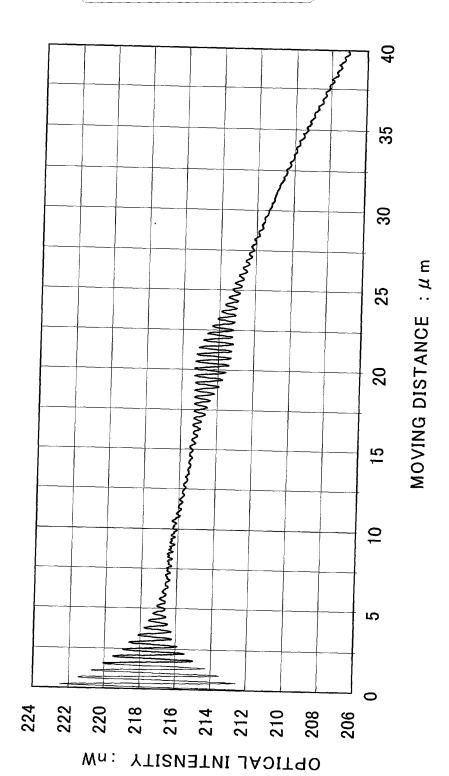
Inventor: Koji OKAMOTO

Page 5 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 6 of 61

FIG. 5B



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Page 7 of 61

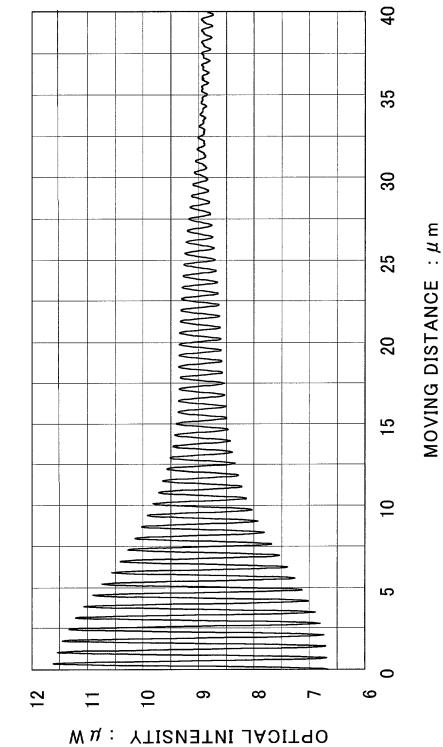
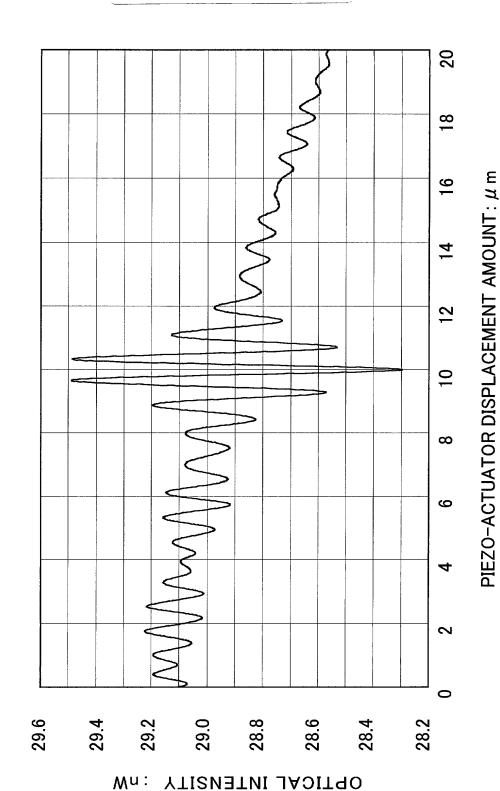


FIG. 6A



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber

Interferosensor and Recording Medium"

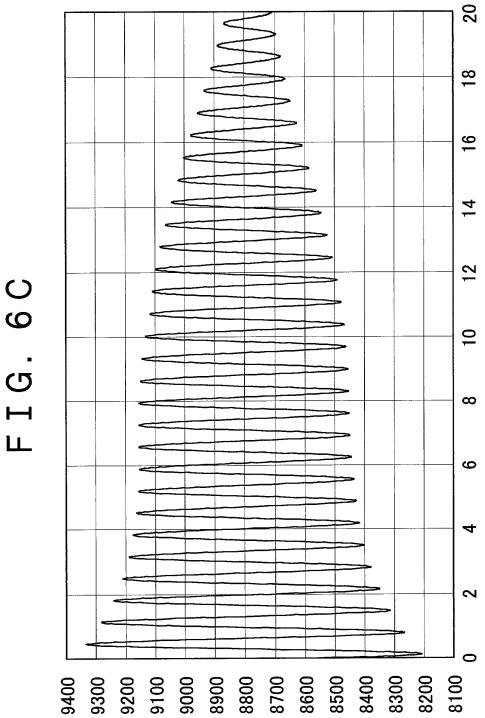
Page 8 of 61

20 $\frac{1}{\infty}$ 16 6 B 9 ∞ 9 219.5 219.0 218.5 217.5 217.0 218.0 216.5 216.0 215.5 215.0 214.5 214.0

OPTICAL INTENSITY

PIEZO-ACTUATOR DISPLACEMENT AMOUNT: μ m

Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, SignalProcessing System for Optical Fiber
Interferosensor and Recording Medium"
Page 9 of 61

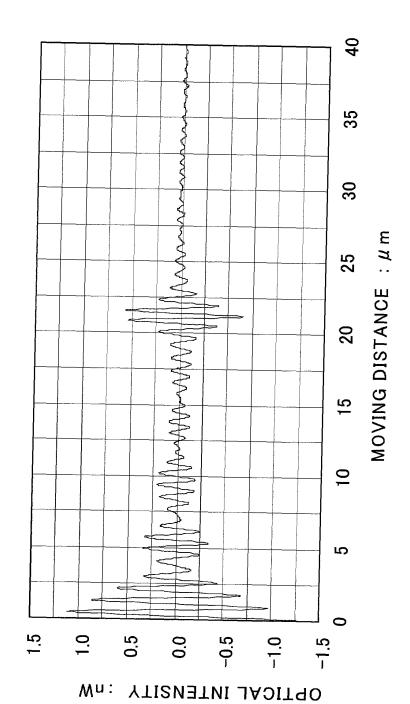


OPTICAL INTENSITY: nW

PIEZO-ACTUATOR DISPLACEMENT AMOUNT: μ m

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 10 of 61

FIG. 7A

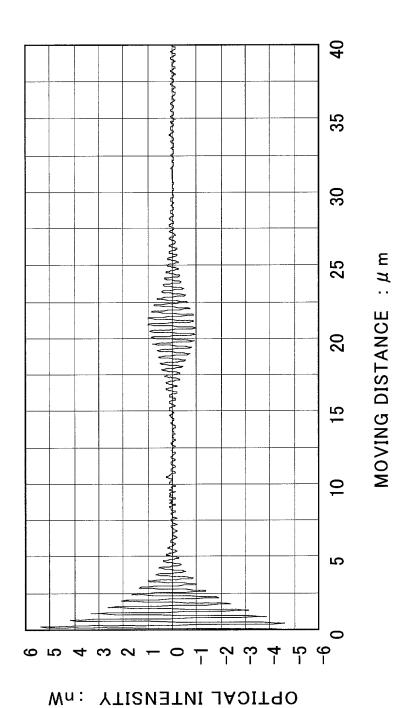


Page 11 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 12 of 61

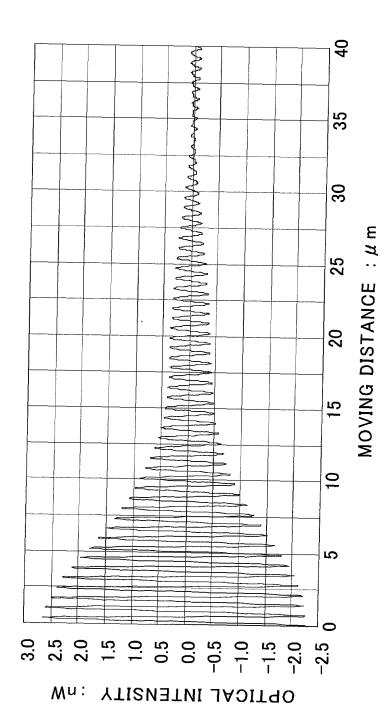
FIG. 7B

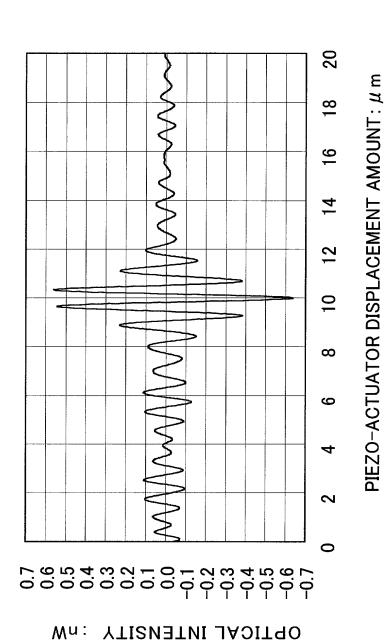


Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Page 13 of 61



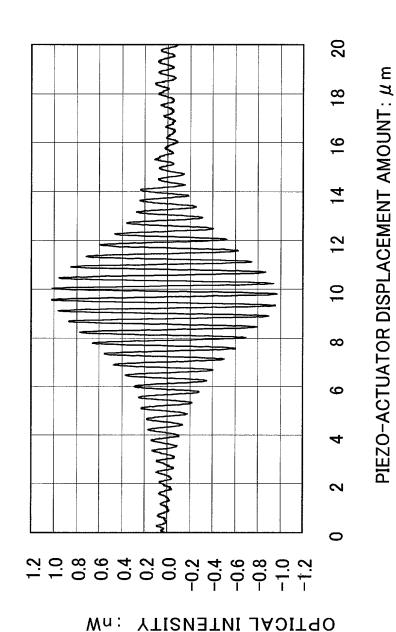




Page 14 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

FIG. 8B



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber

Interferosensor and Recording Medium"

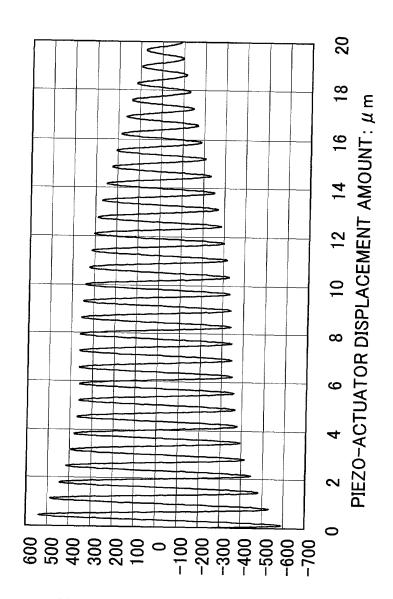
Page 15 of 61

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber

Interferosensor and Recording Medium"

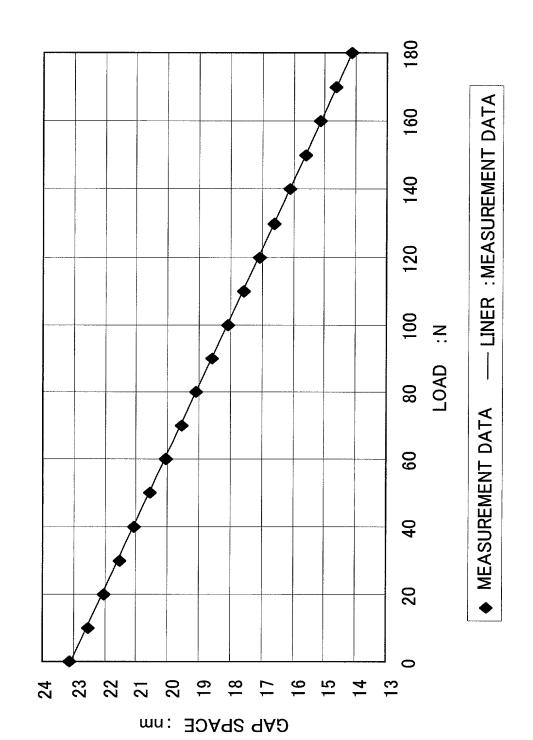
Page 16 of 61

FIG. 8C



OPTICAL INTENSITY : nW

FIG. 9A

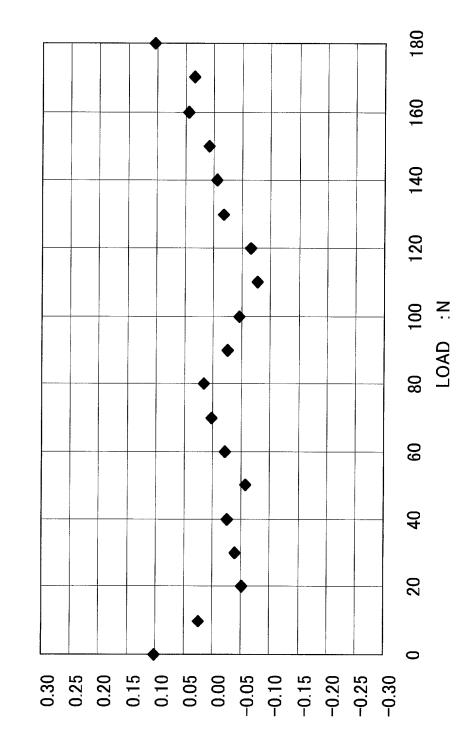


Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-

Processing System for Optical Fiber Interferosensor and Recording Medium"

Page 17 of 61

 \Box တ FIG.



STRAIGHT LINE: %RO

DISPLACEMENT FROM A FITTING

Page 18 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Inventor: Koji OKAMOTO

FIG.

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 19 of 61

09 2 PEROT LOAD 9 FABRY-CELL б 9 PROCESSING SINGNAL PART Ŋ COUPLER 2×2 OPTICAL FIBER CONVERTER 22 23 25 IMAGE SENSOR CONTROLLING 24 **PART**

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 20 of 61

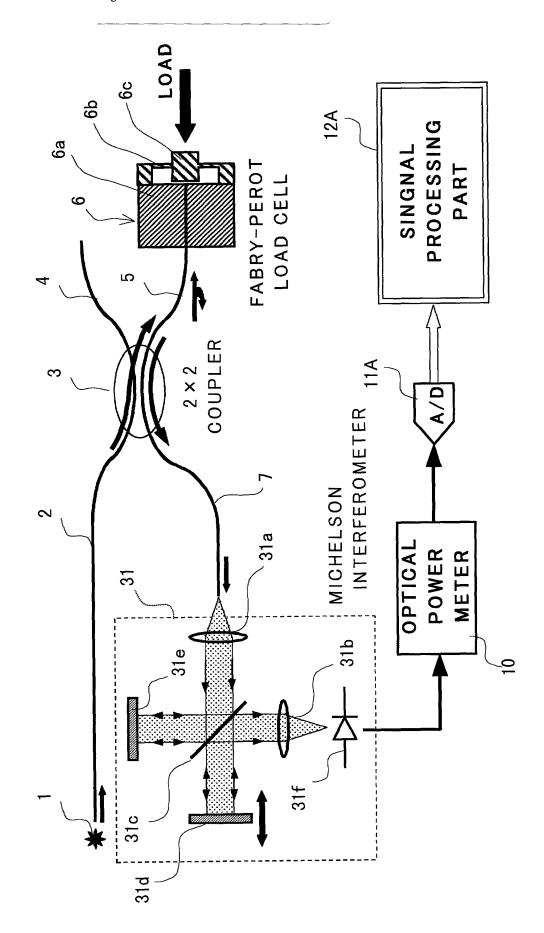
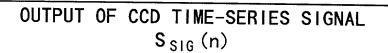


FIG. 11

Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 21 of 61

FIG.12



 $\langle S1 \rangle$ EXTRACTION OF OPTICAL CROSS-CORRELATION SIGNAL $S_{SIG}(n) \Rightarrow S_{LCOR}(n)$

 $S_{LCOR}(n) = S_{SIG}(n) - K \cdot S_{BACK}(n)$

<S2> LPF PROCESSING

 $S_{LCOR}(n) \Rightarrow S_{LCOR, LPF}(n)$

<S3> ELIMINATION OF LOW FREQUENCY COMPONENT WITH MINIMUM SQUARE FITTING

 $S_{LCOR, LPF}(n) \Rightarrow S_{DC}(n)$

<S4> 90° PHASE SHIFT OF WAVEEFORM BY HIRBERT TRANSFORM

 $S_{DC}(n) \Rightarrow S_{90}(n)$ $S_{90}(n) = \hat{H} [S_{DC}(n)]$

<S5> CALCULATION OF AN ENVELOPE (1)

 $S_{DC}(n), S_{90}(n) \Rightarrow S_{ENV}(n)$ $S_{ENV}(n) = \sqrt{S_{DC}(n)^2 + S_{90}(n)^2}$

<S6> CALCULATION OF AN ENVELOPE(2) (LPE PROCESSING)

 $S_{ENV}(n) \Rightarrow S_{ENV, LPF}(n)$

 $S_{ENV, LPF}(n) \Rightarrow dS_{ENV, LPF}(n)/dn$

<S8> CALCULATION OF PEAK POSITION (2) (CALCULATION OF A ZERO POINT POSITION)

 $dS_{ENV, LPF}(X)/dS(X)=0 \Rightarrow X_{PEAK}$

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 22 of 61

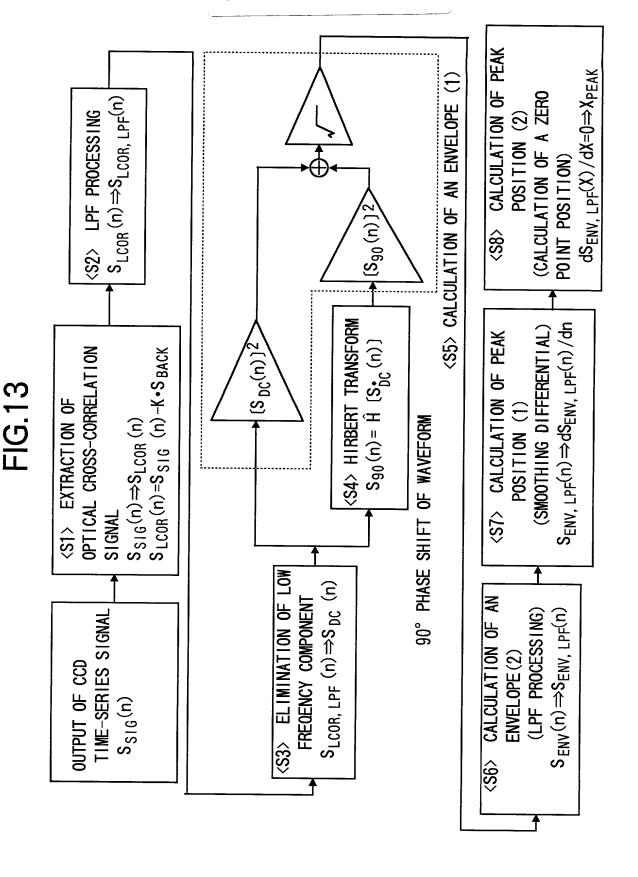
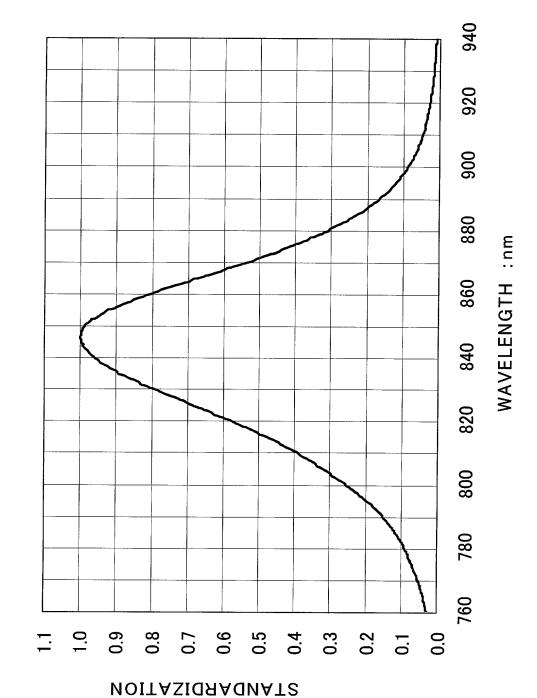


FIG. 14



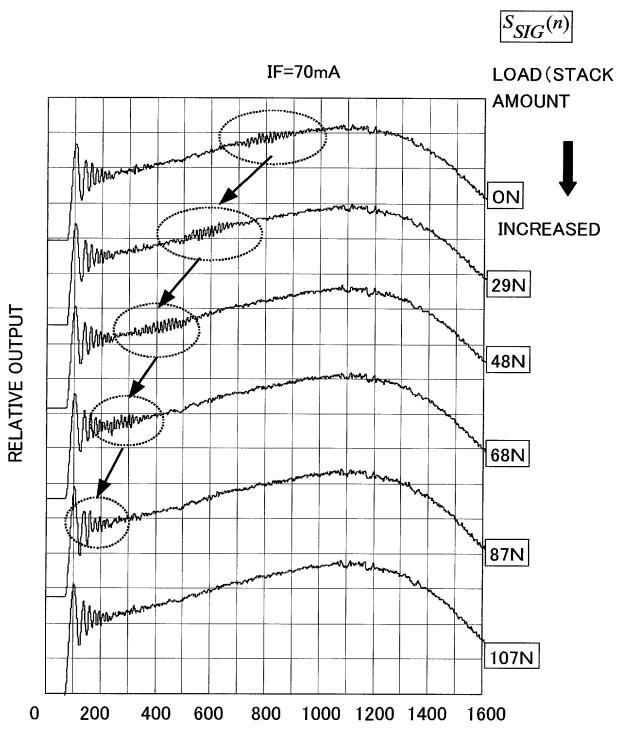
OPTICAL INTENSITY:

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 23 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

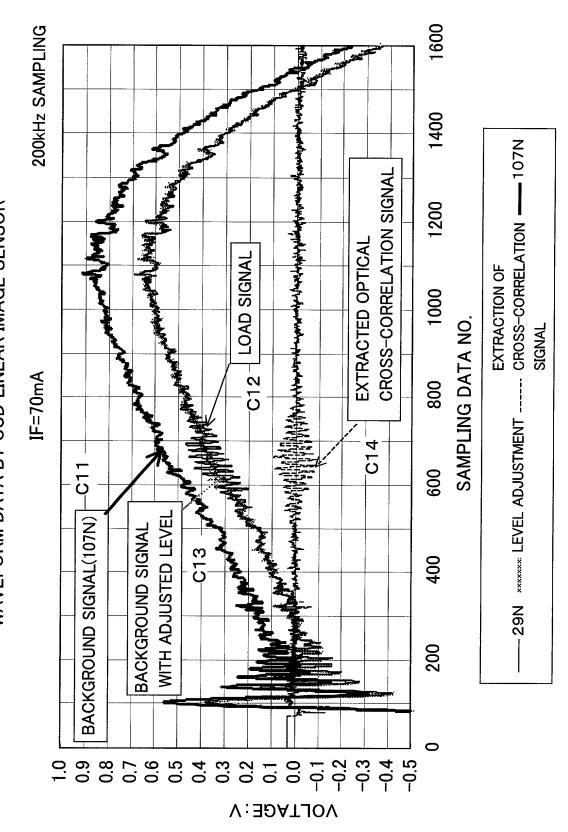
Page 24 of 61

FIG. 15



SAMPLING DATA NO.

WAVEFORM DATA BY CCD LINEAR IMAGE SENSOR 9 FIG.



Page 25 of 61

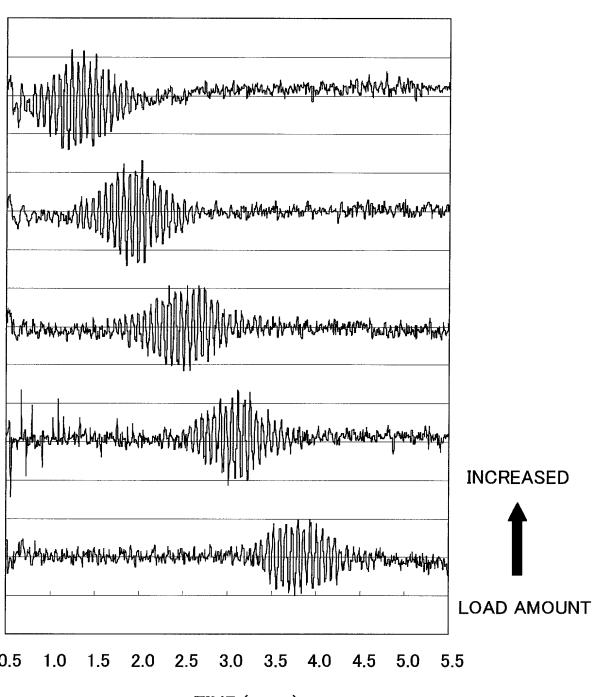
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 26 of 61

FIG.

DETECTION OF OPTICAL CROSS-CORRELATION SIGNAL WITH CCD LINEAR IMAGE SENSOR

S_{LCOR}(n)

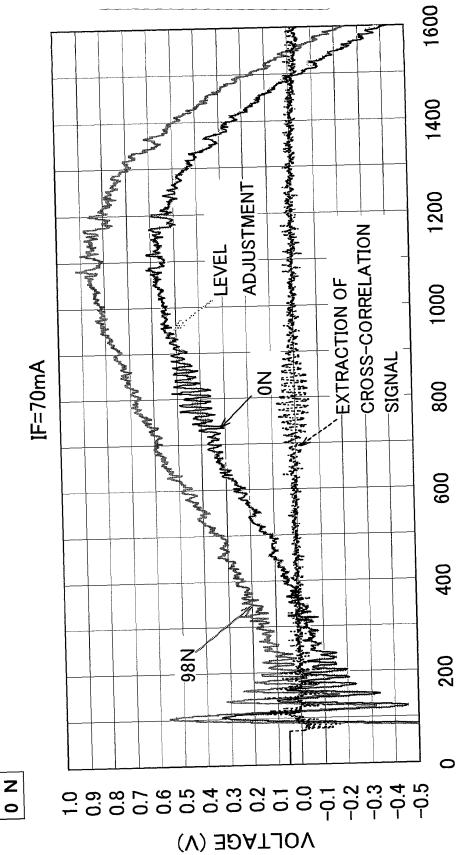
AFTER CORRECTION BY A BIASING VALUE: IF=70mA



0.5

TIME (msec)

FIG. 18A



Page 27 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

SAMPLING DATA NO.

SAMPLING DATA NO.

FIG. 18B

Z

38

Interferosensor and Recording Medium" Page 28 of 61

Inventor: Koji OKAMOTO

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 29 of 61 Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

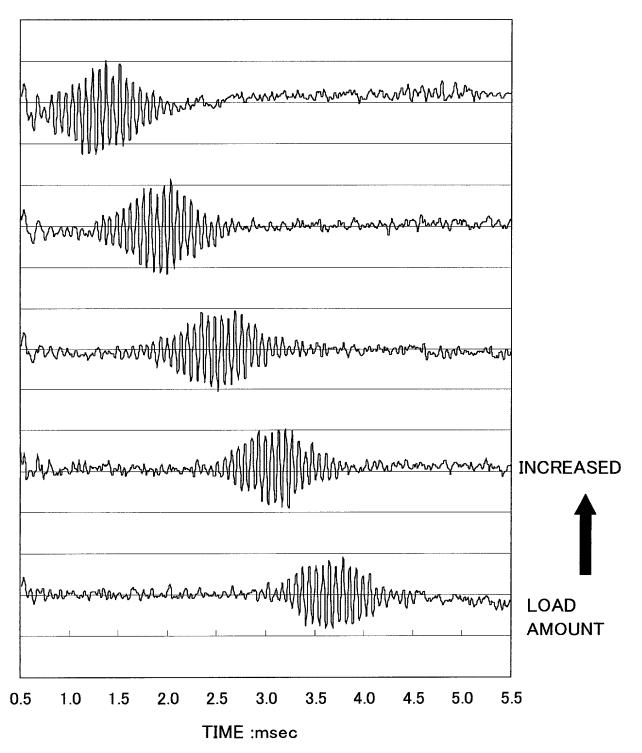
Page 30 of 61

FIG. 19

DETECTION OF OPTICAL CROSS-CORRELATION SIGNAL WITH CCD LINEAR IMAGE SENSOR

S_{LCOR,LPF}(n)

AFTER CORRECTION BY A BIASING VALUE LPF: IF=70 mA

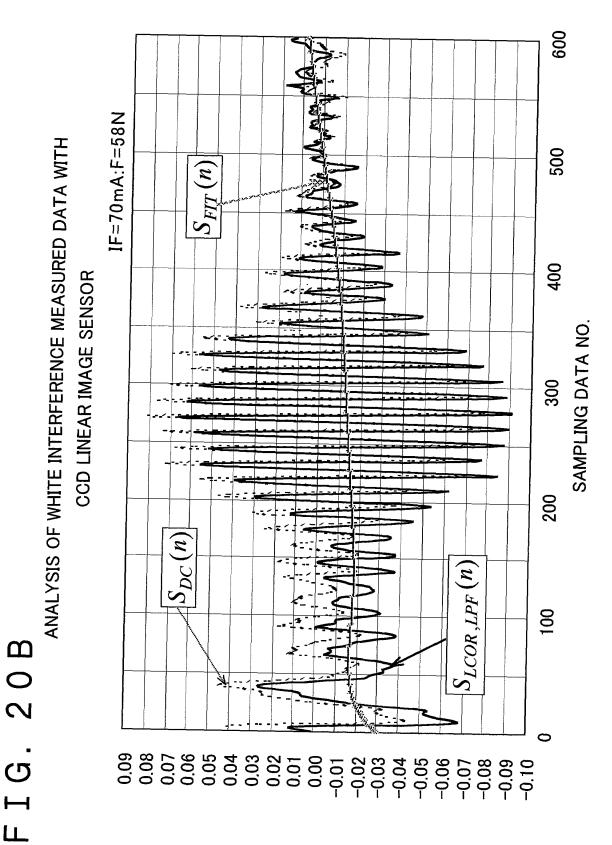


Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 31 of 61

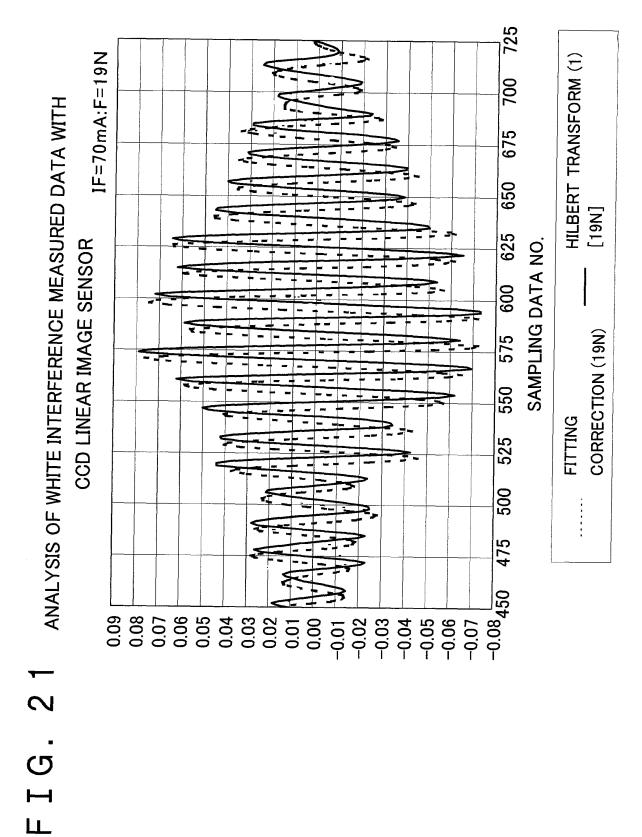
1000 IF=70mA:F=58N zDC900 ANALYSIS OF WHITE INTERFERENCE MEASURED DATA WITH 800 (z)FITCCD LINEAR IMAGE SENSOR 700 SAMPLING DATA NO. 009 $S_{LCOR,LPF}(n)$ 500 400 300 200 20 A 100 0 FIG. $\begin{array}{c} 0.09 \\ 0.08 \\ 0.07 \\ 0.08 \\ 0.005 \\ 0.002 \\ 0.002 \\ 0.002 \\ 0.003 \\ 0.0$

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

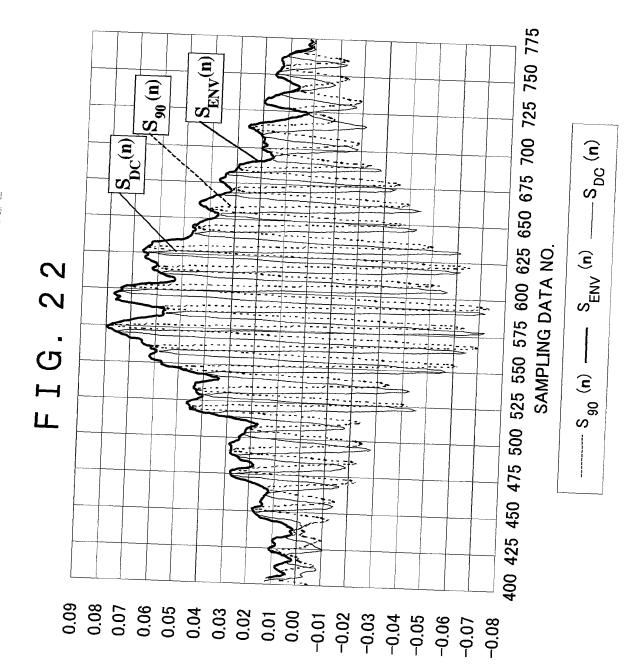
Page 32 of 61



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 33 of 61

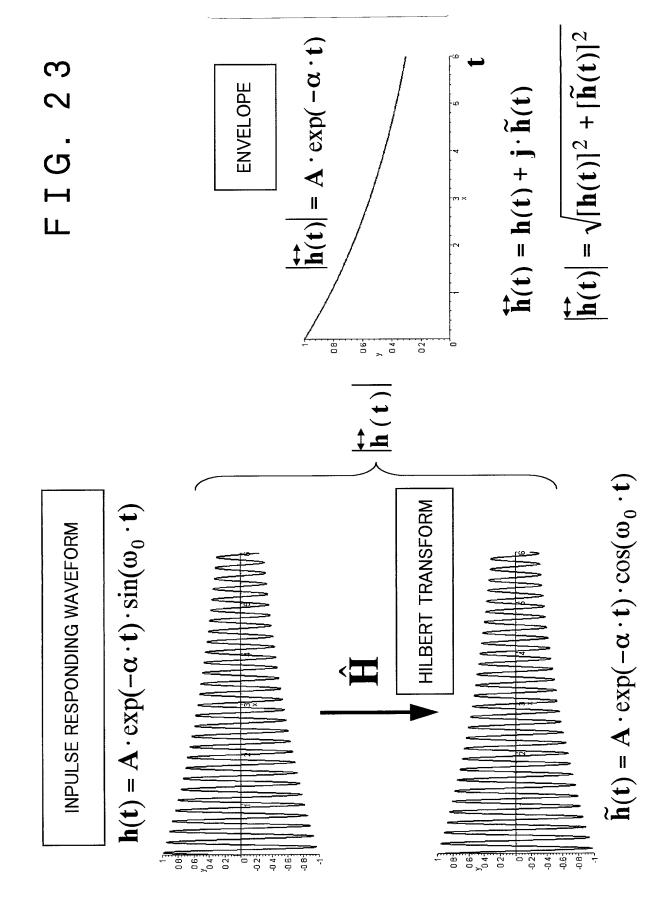


Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 34 of 61



Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Page 35 of 61



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 36 of 61

FIG. 24

0.09

0.08

0.07

90.0

0.05

0.04

0.03

0.02

0.01

..... Senv(n) —— Senv,LPF(n)

900

850

800

750

700

550 600 650

500

450

400

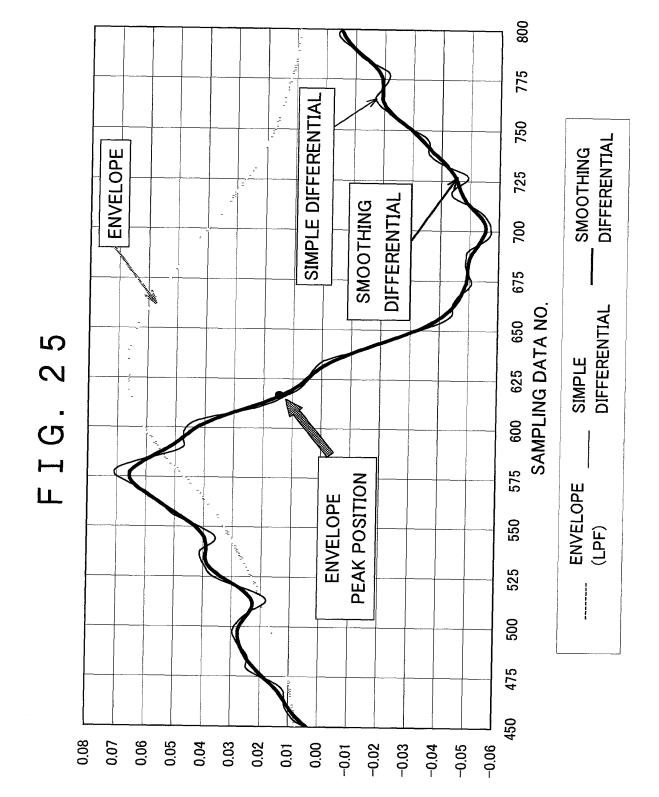
350

300

0.00

SAMPLING DATA NO.

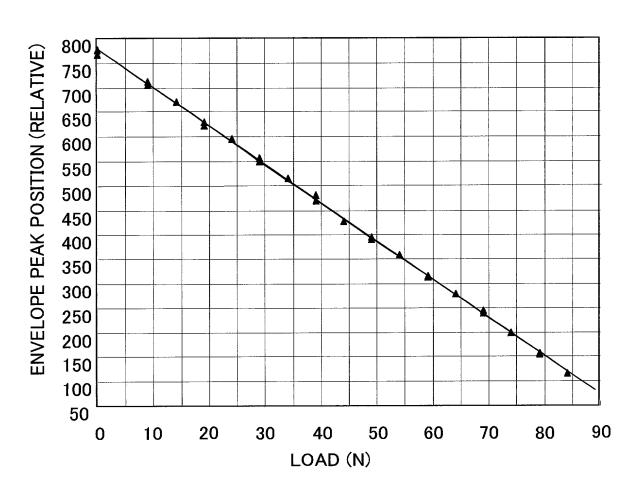
Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 37 of 61



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

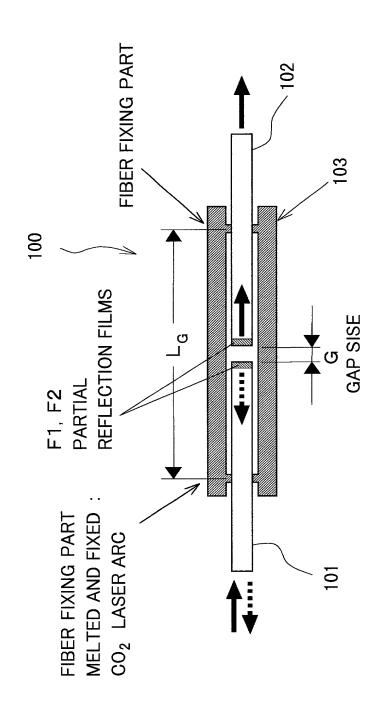
Page 38 of 61

FIG. 26



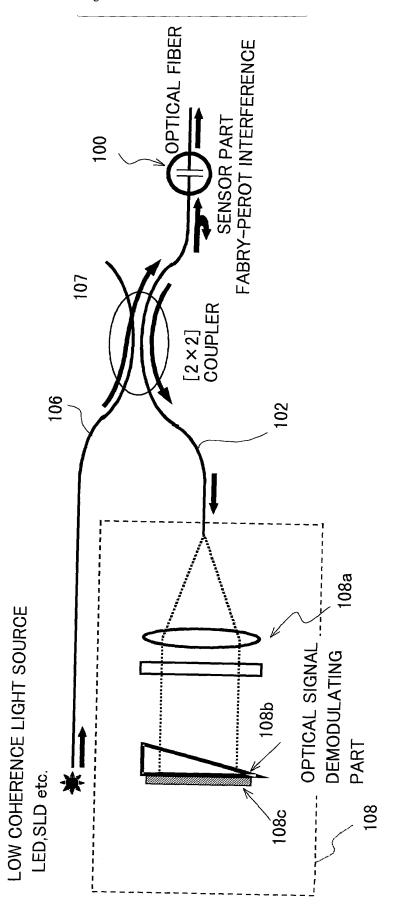
Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 39 of 61

FIG. 27A PRIOR ART



Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 40 of 61

FIG. 27B PRIOR ART

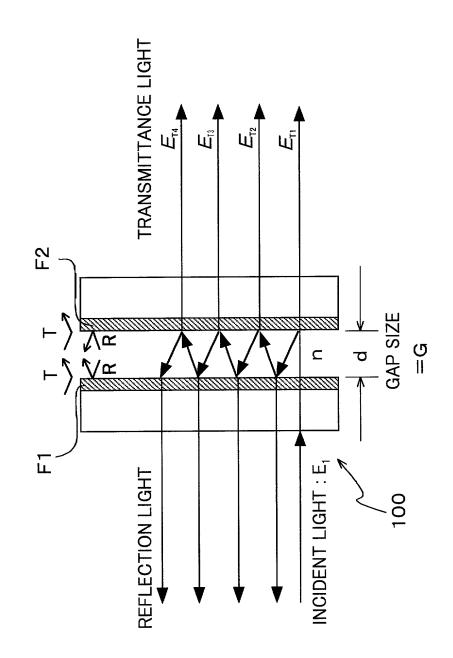


PRIOR ART

2 8

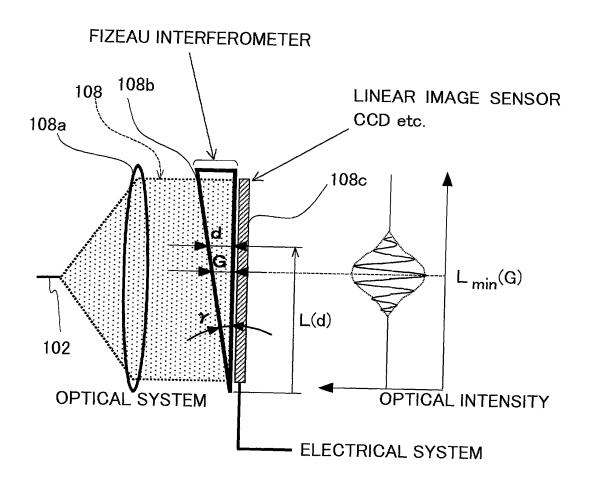
H

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 41 of 61



Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, SignalProcessing System for Optical Fiber
Interferosensor and Recording Medium"
Page 42 of 61

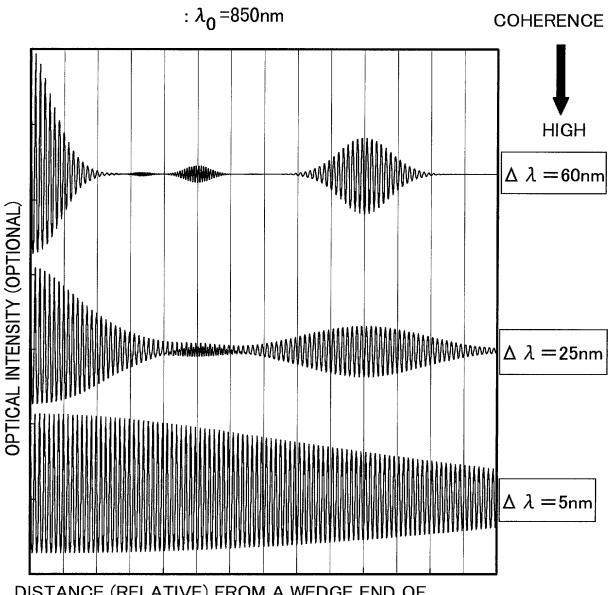
FIG. 29 PRIOR ART



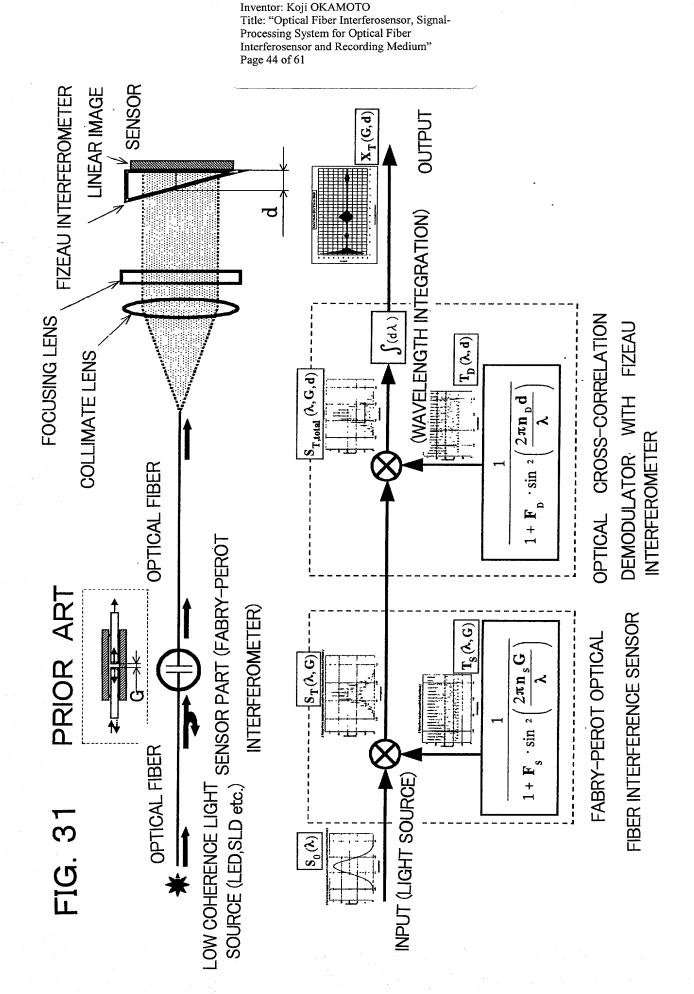
Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 43 of 61

FIG. 30 PRIOR ART

VARIATION OF AN OUTPUT SIGNAL IN RESPECT TO A SPECTRUM WIDTH $\triangle \lambda$ OF A LIGHT SOURCE



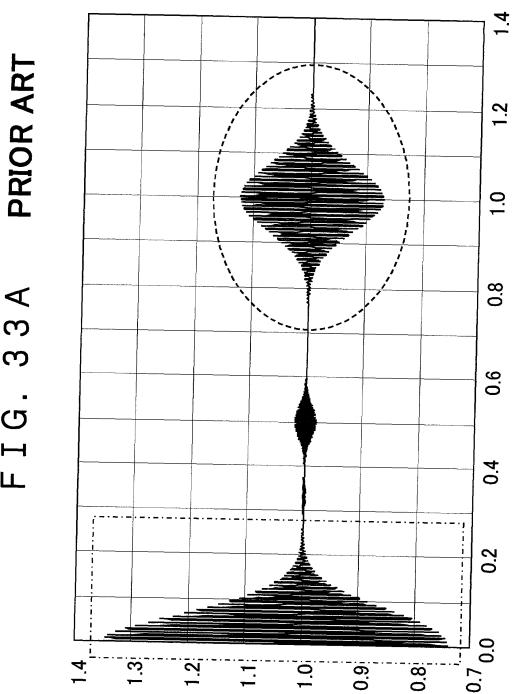
DISTANCE (RELATIVE) FROM A WEDGE END OF A FIZEAU INTERFEROMETER



Interferosensor and Recording Medium" Page 45 of 61 OPTICAL FIBER OPTICAL INTENSITY) SENSOR PART (FABRY-PEROT PRIOR ART INTERFEROMETER X_R (G, d) DISTRIBU DPTICAL CROSS-CORRELATION DEMODULATING PART WITH A FIZEAU INTERFEROMETER **EGRATION**) **TELENGTH** FIG. 32 [D(λ,d) [2×2] COUPLER SR, total (A, G, d) $2\pi n_{\rm n} d$ · sin 2 COLLIMATE LENS 1+ OPTICAL FIBER FIBER INTERFEROMETER Rs (A.G) FABRY-PEROT OPTICAI 2mn G 2πn G FOCUSING LENS · sin ² OPTICAL FIBER F_s · sin² FIZEAU INTERFEROMETER $S_0(\mathcal{R})$ LOW COHERENCE LIGHT SOURCE LINEAR MAGE SENSOR (LED,SLD etc.)

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber

3 3 A



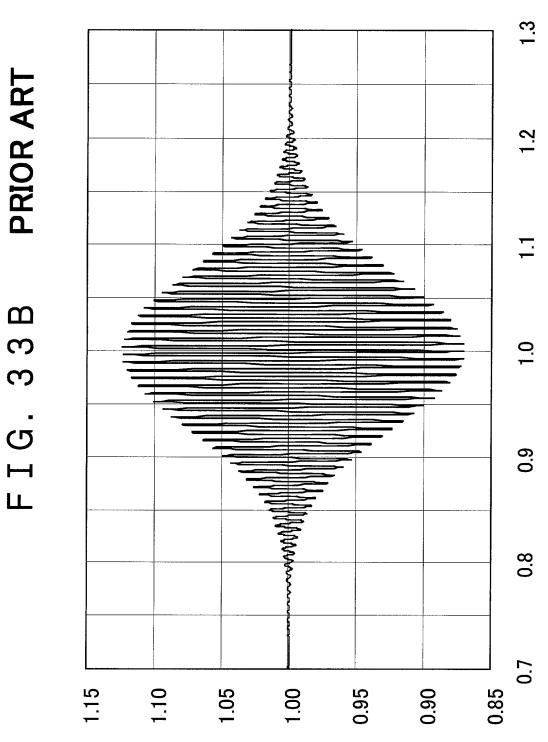
OPTICAL INTENSITY :STANDARDIZATION

DISTANCE (RELATIVE) FROM A WEDGE END OF A FIZEAU INTERFEROMETER

Page 46 of 61

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

OPTICAL INTENSITY: STANDARDIZATION



DISTANCE (RELATIVE) FROM A WEDGE END OF A FIZEAU INTERFEROMETER

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 47 of 61 Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 48 of 61

OPTICAL FIBER Variable gap type fabry-PEROT INTERFEROMETER PIEZO STAGE **PRIOR ART** [2×2] COUPLER FIG. 34A OPTICAL FIBER (G150/125) LOW COHERRENCE LIGHT SOURCE POWER METER LED (850nm) **OPTICAL**

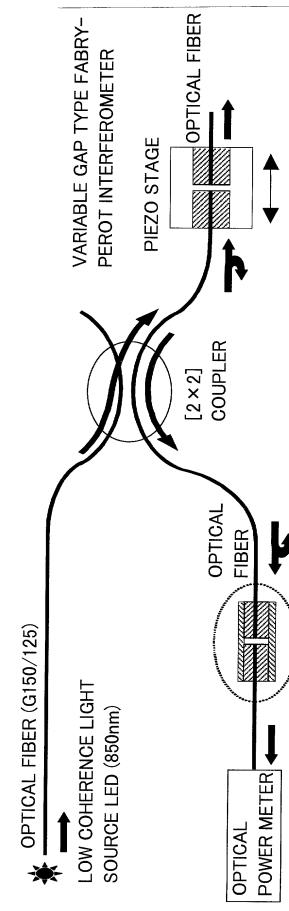
PRIOR ART

3 4 B

FIG.

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Page 49 of 61

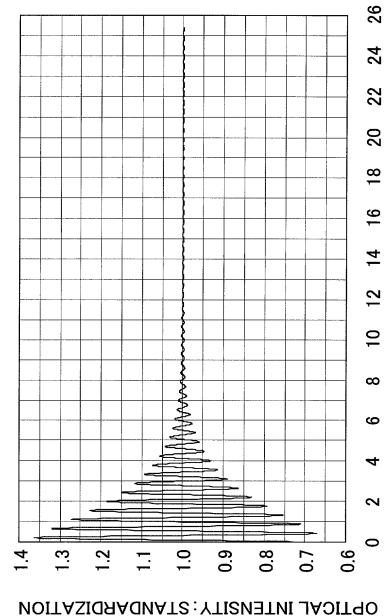


FABRY-PEROT INTERFEROMETER HAVING FIXED GAP

FIG. 35A PRIOR ART

MEASURING SYSTEM WITHOUT FIXED GAP TYPE FABRY-PEROT INTERFEROMETER





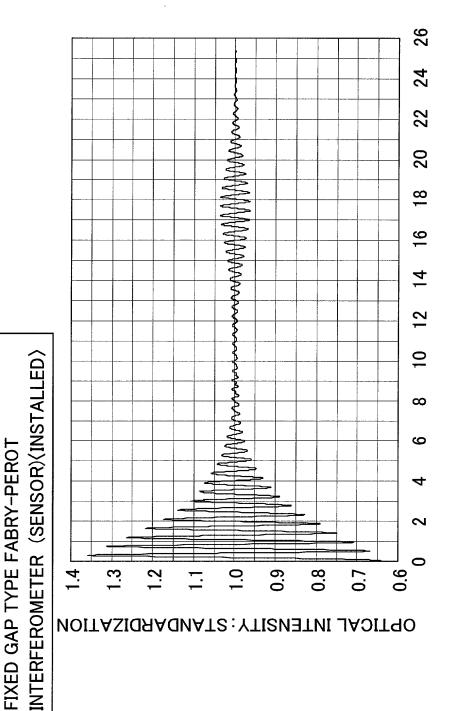
PIEZO-ACTUATOR DISPLACEMENT AMOUNT : μ m

Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, SignalProcessing System for Optical Fiber
Interferosensor and Recording Medium"
Page 50 of 61

The trail that the first that the

PRIOR ART 35B FIG.

MEASURING SYSTEM WITH FIXED GAP FABRY-PEROT INTERFEROMETER



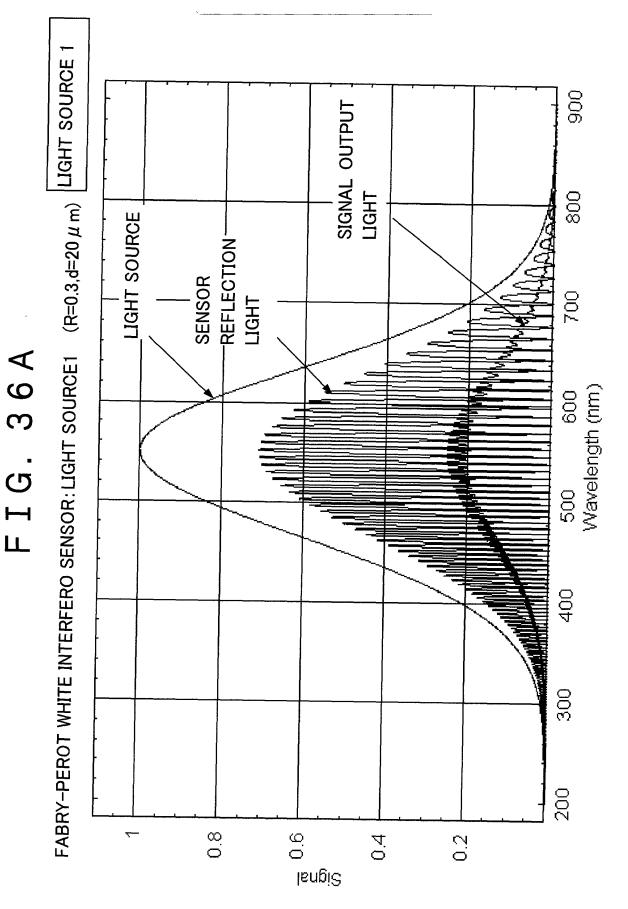
PIEZO-ACTUATOR DISPLACEMENT AMOUNT: μ m

Page 51 of 61

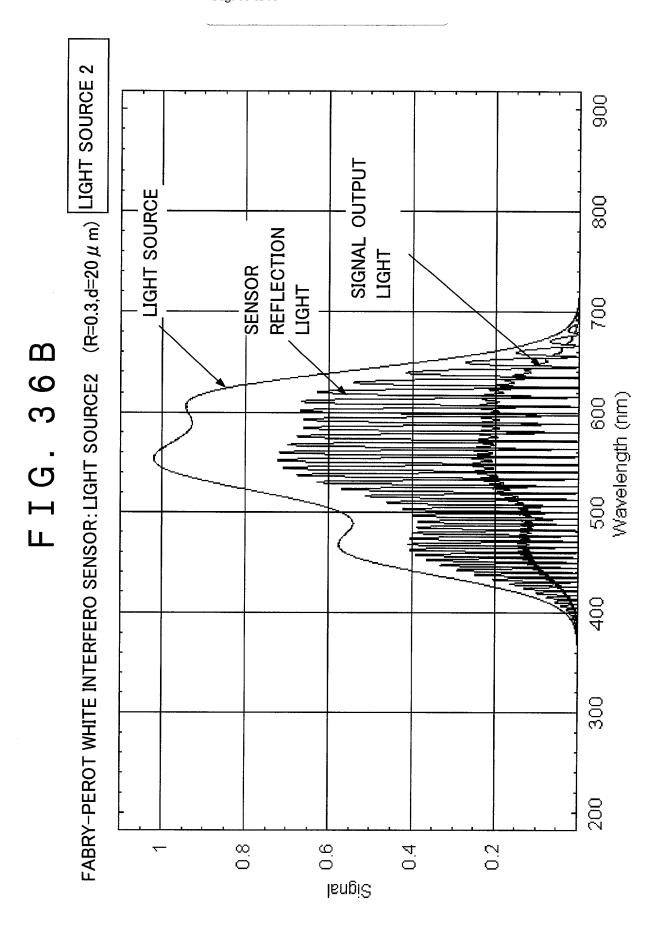
Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

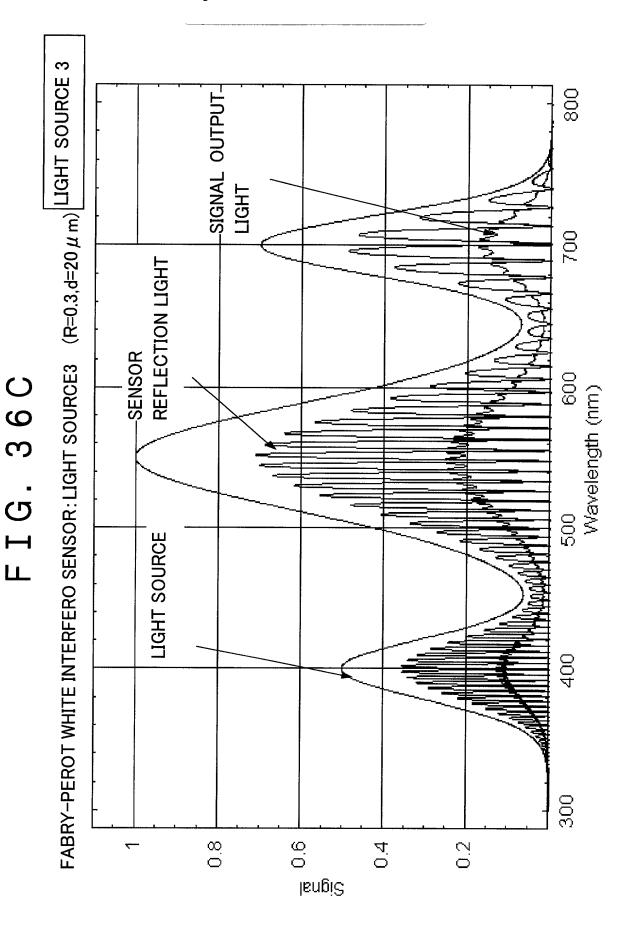
Page 52 of 61



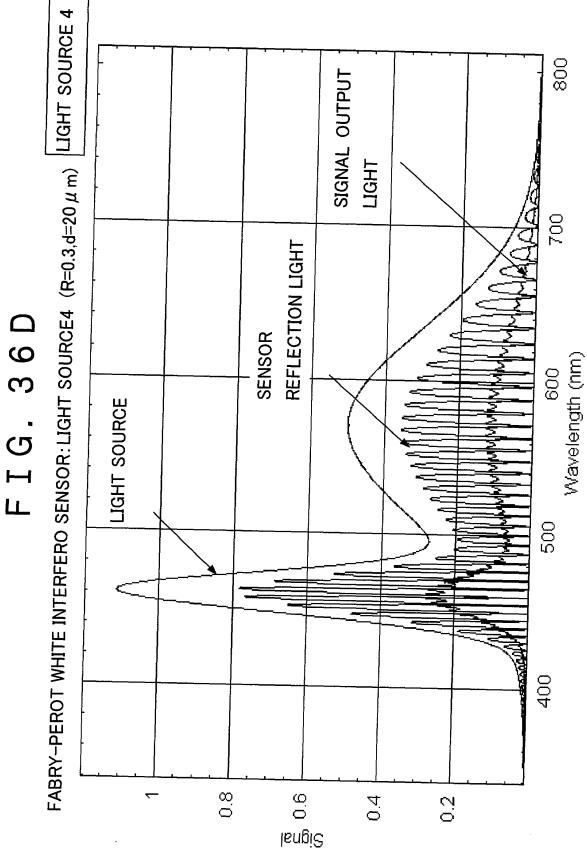
Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 53 of 61



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium" Page 54 of 61



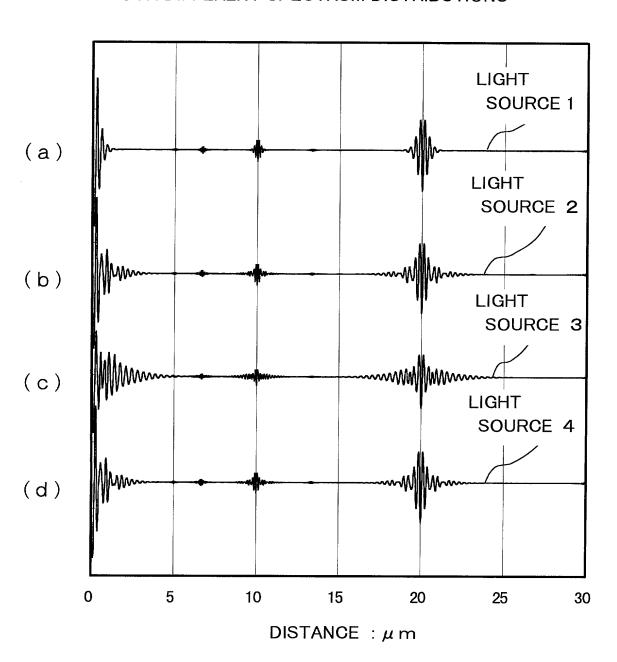
Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, SignalProcessing System for Optical Fiber
Interferosensor and Recording Medium"
Page 55 of 61



Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, SignalProcessing System for Optical Fiber
Interferosensor and Recording Medium"
Page 56 of 61

FIG. 37

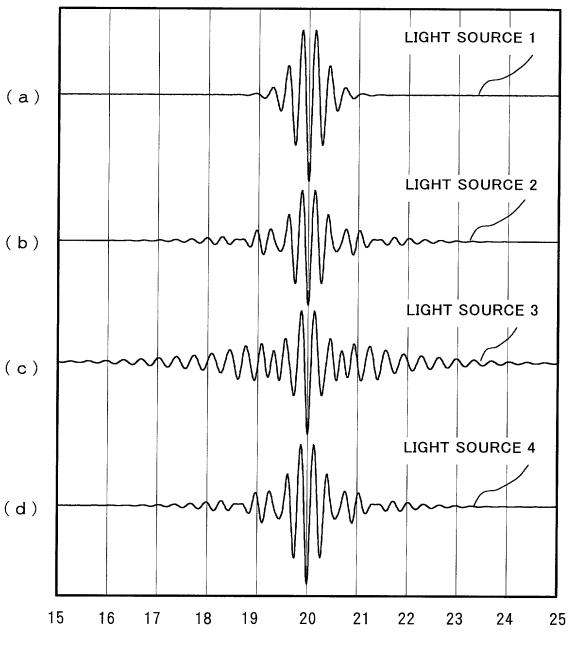
OUTPUT SIGNAL COMPARISON SIMULATION WITH LIGHT SOURCE HAVING FOUR DIFFERENT SPECTRUM DISTRIBUTIONS



Inventor: Koji OKAMOTO Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

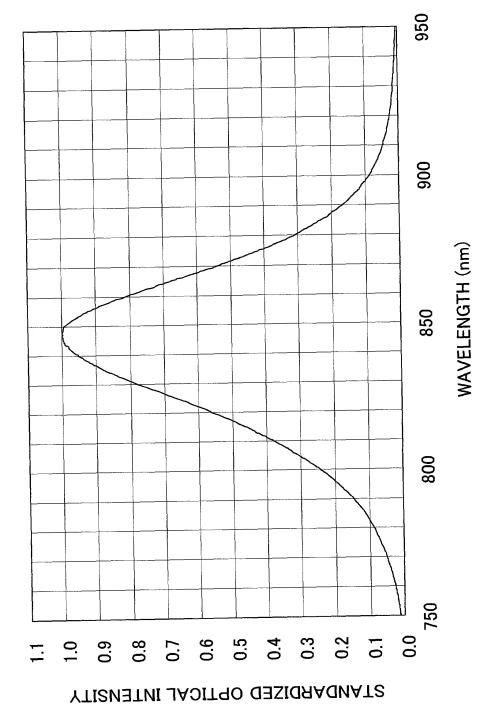
FIG. 38

OUTPUT SIGNAL COMPARISON SIMULATION WITH LIGHT SOURCE HAVING FOUR DIFFERENT SPECTRUM DISTRIBUTIONS



DISTANCE : μ m

FIG. 39A



LED LIGHT SOURCE SPECTRUM COMPARISON

Interferosenso Page 58 of 61

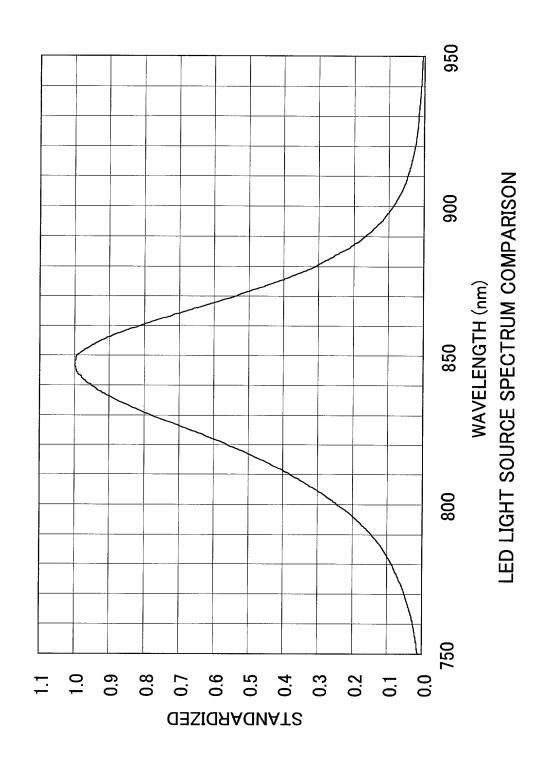
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

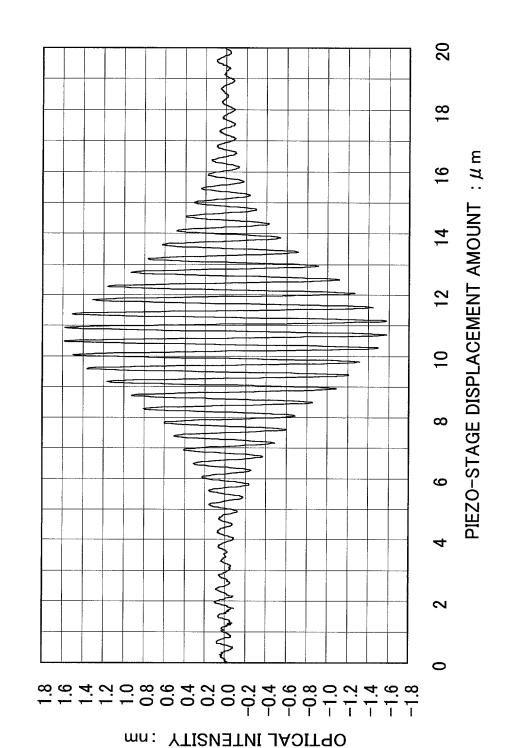
Inventor: Koji OKAMOTO

Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"

Page 59 of 61







Inventor: Koji OKAMOTO

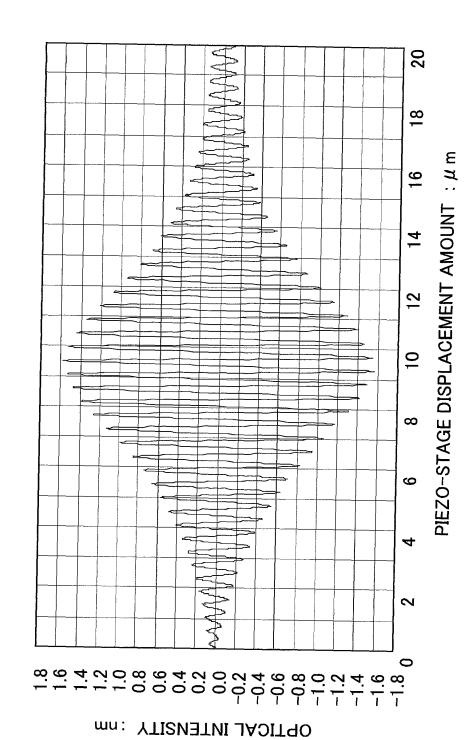
Page 60 of 61

Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber Interferosensor and Recording Medium"

LED LIGHT SOURCE: OPTICAL CROSS-CORRELATION SIGNAL COMPARISON

Inventor: Koji OKAMOTO
Title: "Optical Fiber Interferosensor, Signal-Processing System for Optical Fiber
Interferosensor and Recording Medium"
Page 61 of 61

FIG. 40B



LED LIGHT SOURCE : OPTICAL CROSS-CORRELATION SIGNAL COMPARISON